Nigerian Food Journal

Official Journal of Nigerian Institute of Food Science and Techonology www.nifst.org

NIFOJ Vol. 31 No. 2, pages 98 – 105, 2013

Effects of Particle Size, Applied Pressure and Pressing Time on the Yield of Oil Expressed from Almond Seed

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ABSTRACT

An investigation of the effects of particle size, applied pressure and pressing time on the yield of oil expressed from almond seeds was undertaken. The oil was expressed mechanically using a mini laboratory oil press. The fixed processing parameters were: moisture content of 17% wet basis, heating temperature of 65 - 70°C and heating time of 15 min. The pressing pressures used were 60.6 kPa, 101.3 kPa and 116.6 kPa. Pressing times used were 2, 4, 8 and 12 min, and particle size of $\Phi < 0.5$ mm (fine sample) and $\Phi > 0.5$ mm (coarse sample) were used. The result shows that oil yield increased with increase in applied pressure and pressing time, however result obtained from fine and coarse sample sizes are similar. Pressing time and applied pressure had significant ($p < 0.05$) difference on oil yield; particle size had no significant ($p > 0.05$) difference on oil yield. Regression and correlation analysis gave a reasonable experimental prediction between oil yield and applied pressure with correlation coefficient $r = 0.952$ and also with pressing time with $r = 0.7342$. Higher oil yields were obtained from samples with fine particles size ($\Phi < 0.5$ mm) and coarse particles size ($\Phi > 0.5$ mm) samples pressed at 116.6 kPa pressure for 12 min. Maximum oil yields of 48.44% and 48.40% were obtained from coarse and fine samples respectively. The results obtained can be used in the design of a suitable process and machine for the expression of oil from almond seed.

Keywords: Almond oil, almond seed, applied pressure, particle size, pressing time.

Introduction

The almond (*Prunus dulcis*) is a species of a tree native to the Middle East. It is also the name of the edible and widely cultivated nut of this tree. It is classified with peach in the subgenus *Amygdalus* distinguished from the other subgenera by the corrugated shell (endocarp) surrounding the seed. The edible part of the nut consists of an outer hull and a hard shell with the seed inside. Almonds are commonly sold shelled, i.e. after the shells are removed. Blanched almonds are shelled almonds that have been treated with hot water to soften the seed coat which is then removed to reveal the white embryo (Wikipedia).

The fruit matures in the dry season, 7 – 8 months after flowering. An almond is a true nut; the leaves are 3 – 5 inches with serrated margins. The outer covering or exocarp consists of a thick leathering grey coat called the hull. Inside the hull is a reticulated hard woody shell called the endocarp. The endocarp contains an edible seed. Generally, one seed is present but occasionally there are two (Spiller, 1998).

There are two forms of the plant, one (often with white flowers) producing sweet almonds, and the other with pink flowers producing bitter almonds. The kernel of the former contains a fixed oil and emulsion. As late as the early 20th century, the oil was used internally in medicine, particularly as carrier oil in aromatherapy but has fallen out of prescription among doctors. The bitter almond is rather broader and shorter than the sweet almond,

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and contains about 50% of the fixed oil which also occurs in sweet almond. It also contains the enzyme emulsion which in the presence of water acts as a soluble glucoside, amygalin yielding glucose (Grover *et al.*, 1977).

The sweet almond contains practically no carbohydrates and may therefore be made into flour for cakes and cooking for low-carbohydrate diet for patients suffering from diabetes. Almonds are rich in vitamin E, containing 24 mg/100 g. They are also monounsaturated fat, one of the two good fats responsible for lowering low density lipoprotein (LDL) cholesterol. Health benefits of almond include improved complexion, improved movement of food and prevention of cancer (Porter, 2002).

Almond can be processed into milk substitute called almond milk. The seed's soft texture, mild flavour and light colouring make for an efficient analogue to dairy, and soy-free for lactose-intolerance people. Almond contains 54% oil which is good for application to the skin as an emollient because it is more stable (does not become rancid) than oils that have a higher content of essential fatty acids and because it has a pleasant aroma. It is a mild light weight oil that can be used as a substitute for olive oil (Shipman, 1997).

Almond seed is one of the high oil yielding seeds ever discovered which has oil content as high as 50 – 60% and can be used for edible and industrial purposes (Grieve, 1995). Sweet almond, on expression, yields nearly half its weight in a bland fixed oil. Bitter almond also contains about 50 – 60% of the same fixed oil, and is also free from starch (Grieve, 1995).

The almond oil is a clear pale yellow, odourless liquid with bland, nutty taste. It contains chiefly of olein, with a small proportion of the Glyceride of Linolic acid and other glycerides, but contains no stearin. It is thus similar in composition to olive oil. It is used in trade, being most valuable as a lubricant for the delicate works of watches, and is much employed as an ingredient in toilet soap and cream, e.g. *Venus*, for its softening action on the skin. It forms a good remedy for chapped hands. Other by-products are almond cake, almond butter, almond milk and paste for hands (Wikipedia).

The mechanical expression of oil from oil seeds is one of the methods that are presently used for removing oil from oil-bearing seeds. Oil can also be expressed mechanically by using screw and hydraulic press, oil screw expeller and multi-layer press. The oil yield using this process is dependent on particle size, moisture content, heating temperature, heating time, applied pressure and pressing time (Khan and Hanna, 1983).

Carr (1997) suggested, with the exception of very small seeds such as sesame, that reduction of oil seed to flakes is essential. The size and hardness of oil seeds determine the number of stages for the flaking operation without which oil yield is reduced. Generally, smaller-size pieces are better for oil removal, but if the pieces are too small, they may contaminate the oil and be difficult to remove from the final product (Taylor and Francis, 2003).

Ward (1976) reported that heating of oil seeds after size reduction increases oil yield due to breakdown of oil cells, coagulation of protein in the seed which renders oil separable from the meal without expulsion of proteinacious fraction and decreases oil viscosity, which allows the oil to flow more readily. Reports from several researchers show that the temperature and duration of heating have significant effect on oil yield (Pominiski *et al.*, 1970 and Bongirwar *et al.*, 1977).

According to Anjou (1972) and Ohlson (1976), high heating temperatures and long heating times may have negative effects on the quality of expressed oil and cake residue. Koo (1937) showed that the oil yield from oil seeds was directly proportional to the square root of the pressure. Ohlson (1976) concluded in his study that processing conditions can have a strong effect on oil quality.

In this work, the effect of particle size, applied pressure and pressing time on oil yield from almond seed was investigated.

Materials and Methods

The almond seeds used in this study were collected freshly from almond trees; the fruits were dried and cracked. The seeds were grinded with an attrition mill and sieved using 0.05 mm aperture sieve to separate into fine and coarse sample. The initial moisture content of the sample was determined by oven method, where 100 g of sample was dried in the oven at 130°C for 6 h as stipulated by ASAE (1983) Standard S410. The moisture content was expressed in the wet basis percentage of the dry matter. The sample was conditioned to the required moisture content by adding calculated amount of water based on the following equation:

Weight of water to be added (g)

$$= \frac{\text{Weight of sample x (required \% MC)} - \text{(Initial \% MC)}}{100 - \text{(Required \% MC)}} \quad (1)$$

The conditioning was done for two (2) weeks by keeping the sample in refrigerator at about 5 – 10°C. The actual percentage moisture content after the conditioning was determined and recorded.

Factors considered in this study and their levels were selected based on preliminary experiment and review of literature on oil expression from oil seeds in general. The fixed processing parameters were heating time of 15 min, heating temperature of 65 – 70°C and moisture content of 17% wet basis. The applied pressure was varied at 60.6 kPa, 101.3 kPa and 116.6 kPa, pressing time of 2, 4, 8 and 12 min were used, and two particle sizes – fine sample of $\Phi < 0.5$ mm and coarse sample of $\Phi > 0.5$ mm.

Heating was done by spreading 50 g of the sample in thin layer on a closed container placed in a preset temperature controlled Gallenkamp OV 440 oven for 30 min.

The sample was then wrapped in cheese cloth and fed into the pressing cylinder, different pressing pressures: 116.6, 101.3 and 60.6 kPa were used by adding varying known weight to the pressing arm of the laboratory oil press. The oil yield (%) was based on the weight of the material in the pressing cylinder before pressing. The yield for the different processing parameters combination was measured and recorded in terms of % weight. The per cent oil yield is defined as:

$$Y = \frac{W_1 - W_2 \text{ x } 100\%}{W_1} \quad (2)$$

Where,
W_1 = weight of unexpressed sample (kg)
W_2 = weight of expressed sample (kg)
Y = Oil yield (%)

Statistical analysis

Factorial experiment was used in this study, which allows the effects between and within the parameters to be tested simultaneously. Data obtained from the experiment was analysed using (ANOVA) at 5% confidence level. Regression and correlation was performed using the least square regression line model.

Results and Discussion

The effect of particle size and applied pressure

The effect of particle size and applied pressure on oil yield at pressing time of 12 min is presented in Table 1.

Table 1: The effect of particle size and applied pressure on the % almond oil yield (mean)

Particle size	Applied pressure (kPa)		
	60.6	101.3	116.6
Fine	41.60	44.72	48.40
Coarse	34.14	40.20	48.44

The effects of applied pressure and pressing time on particle size

The effect of applied pressure and pressing time on the two particle sizes (fine and coarse) is presented in Tables 2 and 3.

Table 2: Effect of applied pressure and pressing time on the % almond oil yield (mean) for fine particle size (Φ < 0.5 mm).

Applied Pressure (kPa)	Pressing time (min) 2	4	8	12
60.6	24.74	24.92	25.62	41.60
101.3	36.72	46.04	43.74	44.72
116.6	37.48	47.34	48.26	48.40

Table 3: Effect of applied pressure and pressing time on the % almond oil yield from coarse particle size (Φ > 0.5 mm)

Applied pressure (kPa)	Pressing time (min) 2	4	8	12
60.6	28.56	29.16	29.76	34.14
101.3	25.62	32.26	34.68	44.72
116.6	32.42	37.76	41.52	48.40

Results of statistical analyses

The summary of the results for ANOVA and regression and correlation analysis is presented in Tables 4 to 7. The linear model used is shown in eq. 3.

Table 4: ANOVA table for the effect of particle size and applied pressure

Source of error	Sum of square	Degree of freedom	Mean of square	F	Sig.
Within sample	111.9	2	55.95	7.803	0.000
Between sample	23.76	1	23.76	3.314	0.000
Errors	14.34	2	7.17		
Total	150	5			

Table 5: ANOVA table for the effects of applied pressure and pressing time (fine particle size)

Source of error	Sum of square	Degree of freedom	Mean of square	F	Sig.
Within sample	213.87	3	71.29	3.379	0.000
Between sample	602.6	2	301.3	14.280	0.000
Errors	126.62	6	21.10		
Total	943.09	11			

Table 6: ANOVA table on the effect of applied pressure and pressing time (coarse particle size)

Source of error	Sum of square	Degree of freedom	Mean of square	F	Sig
Within sample	227.33	3	75.78	3.3059	0.000
Between sample	196.47	2	98.235	4.2854	0.000
Errors	137.53	6	22.923		
Total	561.33	11			

Table 7: Summary of regression and correlation coefficients

Oil yield (Y%) on	A	b	R
Applied pressure (kPa)	0.112	34.51	0.952
Pressing time (min.)	0.874	39.69	0.734

»Linear model: $Y = ax + b$ (3)

Discussion

Presentation from Table 1 shows that oil yield increased with increase in applied pressure for both coarse and fine particle samples. There is no significant ($p > 0.05$) difference in the oil yield obtained at the different applied pressure between the fine and coarse particle size samples. The main determinant of oil yield is the pressing time, which agrees with the findings of Fashina and Ajibola (1989) on the effect of applied pressure on fine particle size samples of conophor seeds.

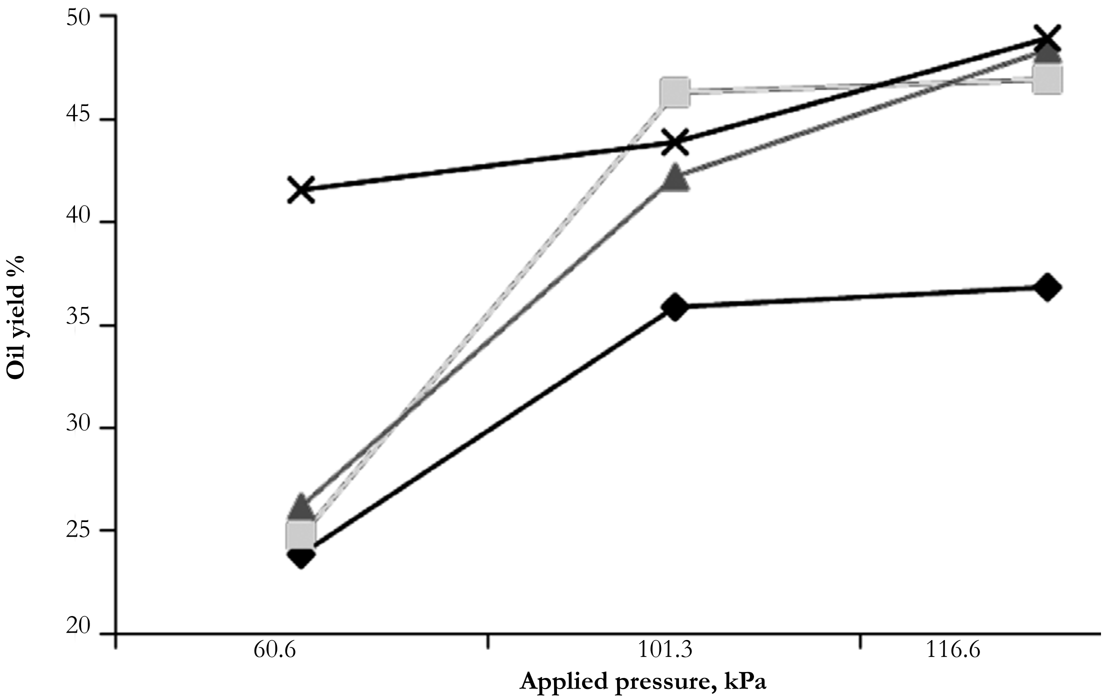

Fig. 1: Oil yield versus applied pressure for fine samples pressed for different pressing time of (◊), 2 min; (□), 4 min; (Δ), 8 min; and (x), 12 min

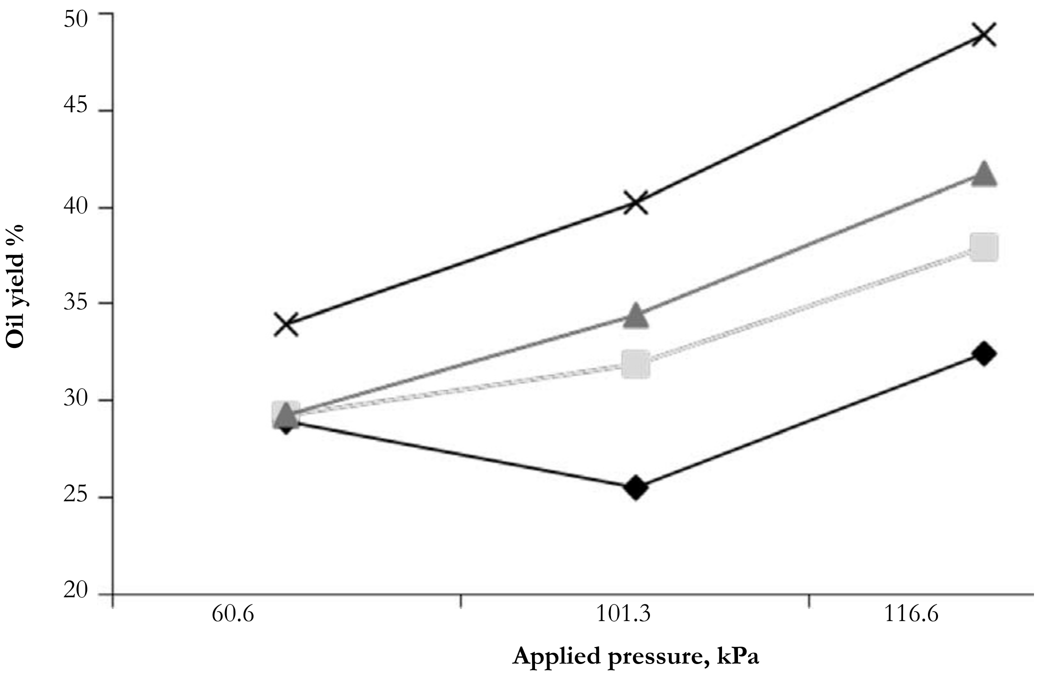

Fig. 2: Oil yield versus applied pressure for coarse samples pressed for different pressing time of (◊), 2 min; (□), 4 min; (Δ), 8 min; and (x) 12 min

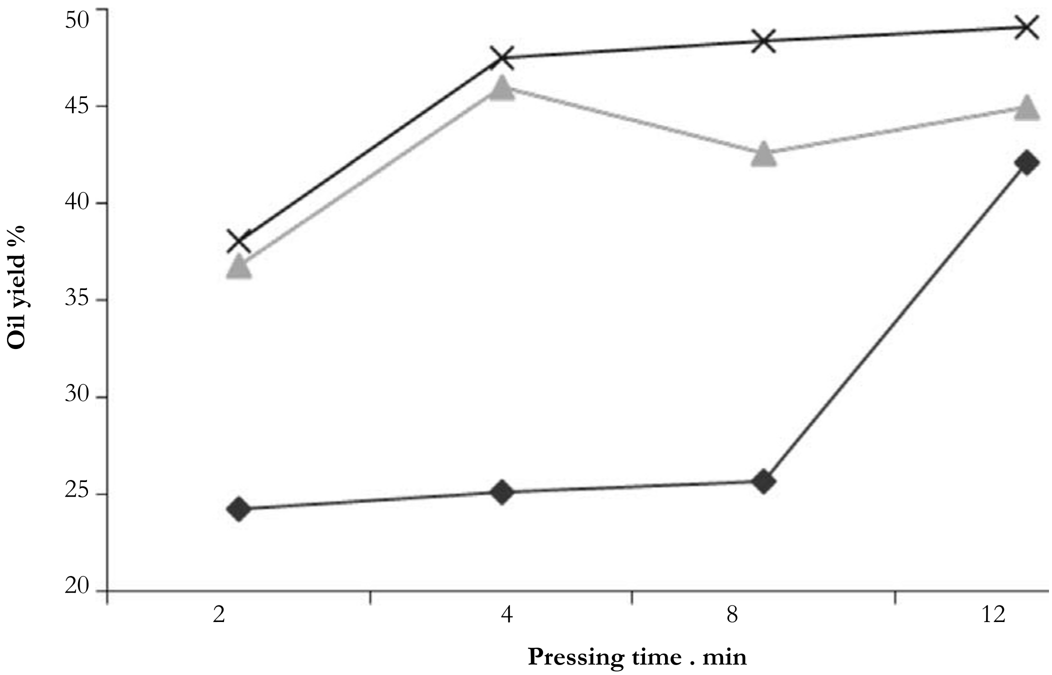

Fig. 3: Oil yield versus pressing time for fine samples pressed at different pressure of (◊), 60.6 kPa; (Δ), 101.3 kPa; and (x) 116.6 kPa

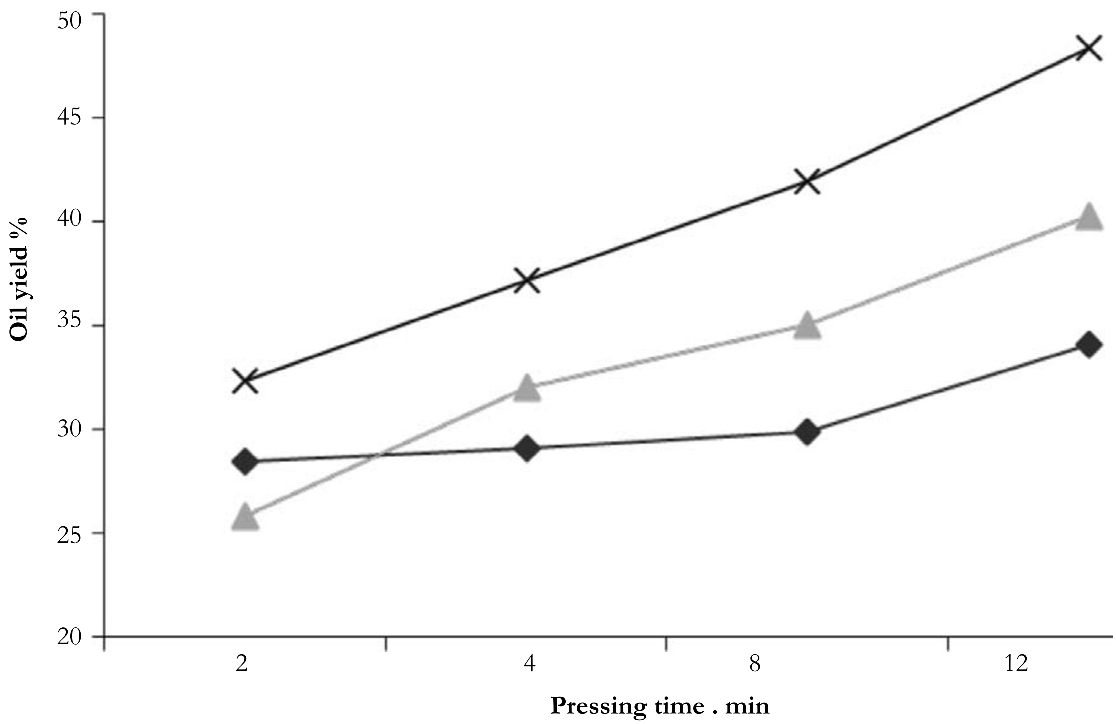

Fig. 4: Oil yield versus pressing time for coarse samples pressed at different pressure of (◊), 60.6 kPa; (Δ), 101.3 kPa; and (x) 116.6 kPa

In Tables 2 and 3, oil yield increased as the pressing time increased for all the pressure applied on both the fine and coarse samples. There is significant ($p < 0.005$) difference in percentage oil yield obtained at the different pressing times. This can be said to be true for most oil seeds as reported for melon (Ajibola, 1988) and conophor seed (Fashina and Ajibola, 1989). If oil were to be expressed at a pressure of 60.6 kpa, more time will be needed before maximum yield will be obtained. However, the same amount of oil obtained after 12 min from 60.6 kPa would have been obtained within the first three minutes from 116.6 kPa applied pressure. There is also significant ($p < 0.05$) difference in oil yield at different applied pressure and pressing times.

The maximum oil yield obtained at 116.6 kpa for 12 min was similar for both particle size samples, that is, 48.44% and 48.40% for coarse and fine particle size samples respectively. There is no significant ($p > 0.005$) difference in the oil yield obtained at the different particle sizes, as was the case of conophor seed (Fashina and Ajibola, 1989). This shows that particle size within the range of 0.5 – 1.0 mm and below will be suitable for mechanical expression of oil from almond seed. Figures 1 and 2 also show graphically that oil yield increased with increase in applied pressure and pressing time.

Using a linear least square regression line procedure, coefficient of correlation $r = 0.952$ was obtained for regression of oil yield on applied pressure showing that there is a high correlation between oil yield and applied pressure. The model is given in eq. 4:

$$Y(\%) = 0.112P\ (\text{kPa}) + 34.51 \tag{4}$$

Also, correlation coefficient $r = 0.734$ was obtained for regression of oil yield on pressing time, indicating that there exists a high correlation between oil yield and pressing time. The model is given in eq. 5.

$$Y(\%) = 0.874t\ (\text{minutes}) + 39.69 \tag{5}$$

The summary of the regression and correlation coefficients is presented in Table 7.

Conclusion

Applied pressure and pressing time had significant ($p < 0.05$) effect on percentage oil yield from almond seed while particle size had no significant ($p > 0.005$) effect on percentage oil yield. Least Square Regression Line Model predicted high correlation between oil yield and applied pressure and also with pressing time with high values of correlation coefficient, r.

Maximum oil yield were obtained from coarse and fine particle sizes when oil was pressed from almond seed at applied pressure of 116.6 kPa and pressing time of 12 min. Increasing pressure indefinitely has little or no effect on percentage oil yield because maximum possible oil content of about 50% can be obtained from almond seeds at a pressure of about 130 kPa.

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